WISH Canada

Canadian Perspective and Interests

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WISH International Science Workshop, Marseille 2014

WISH Canada

- who we are -

What do Canadians WISH for?

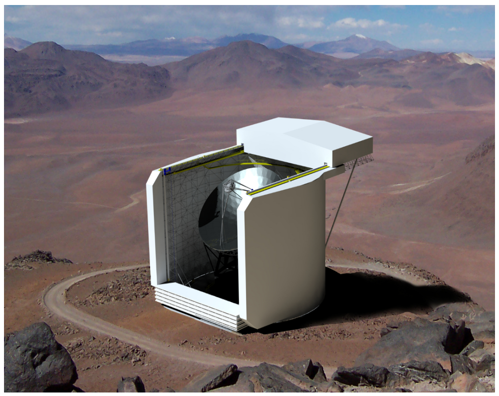
+ luminous First Light sources *(of course!)*
+ Dark Energy (CFHTLS heritage)

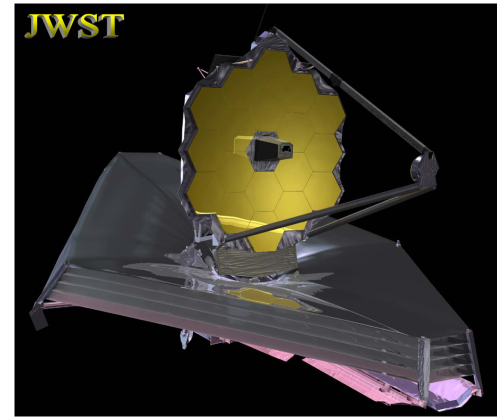
...but we also WISH for...

+ galaxy evolution out to z~5
+ galaxy clusters out to z~2
+ stellar populations in nearby galaxies
+ Solar System objects

WISH in the Canadian context

CCAT





JWST

ALMA

TMT

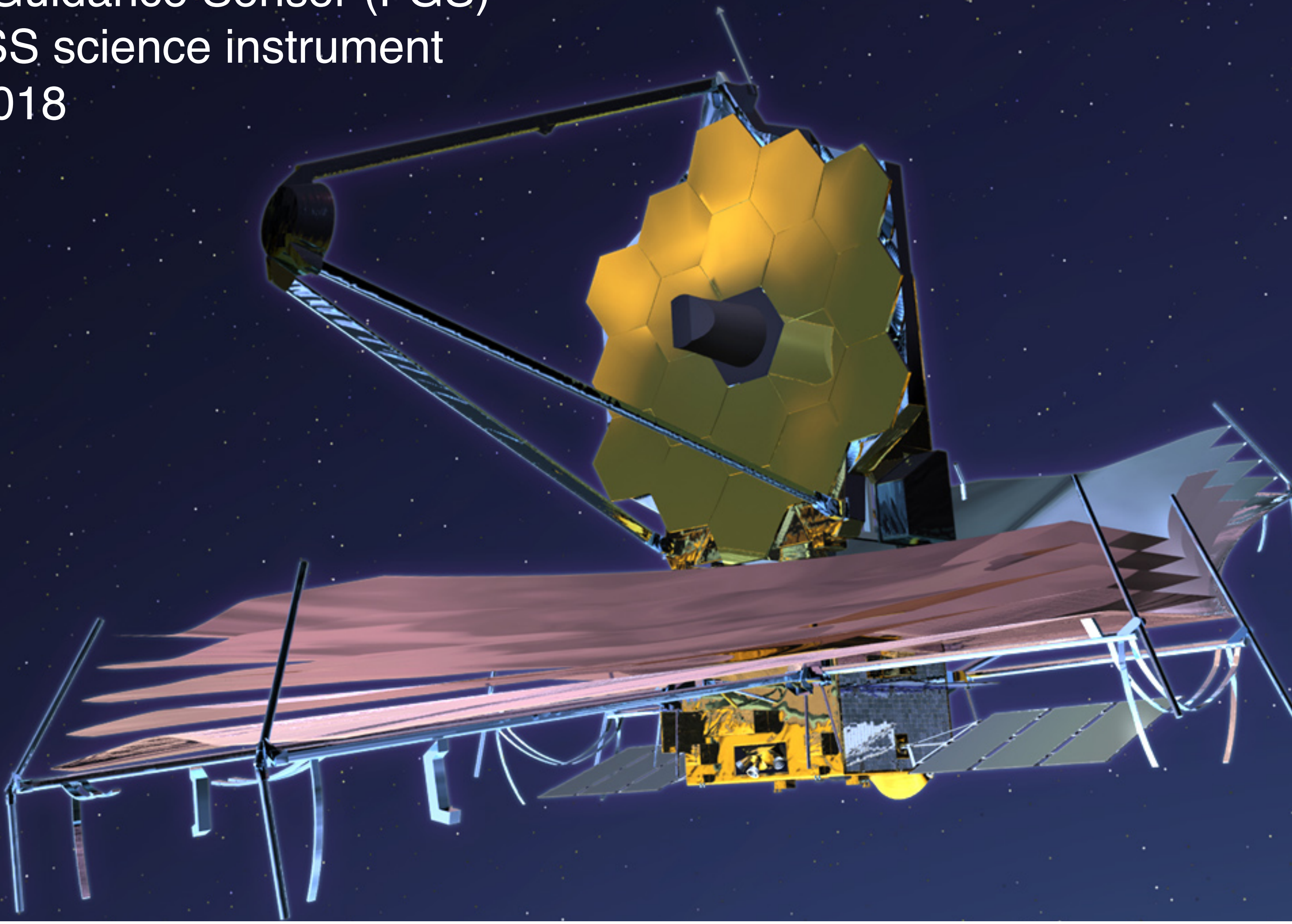
Gemini (x2)

JCMT

CFHT

JWST

- Canadian Space Agency (CSA) one of the three partners
- Canada responsible for:
  - Fine Guidance Sensor (FGS)
  - NIRISS science instrument
- Launch 2018



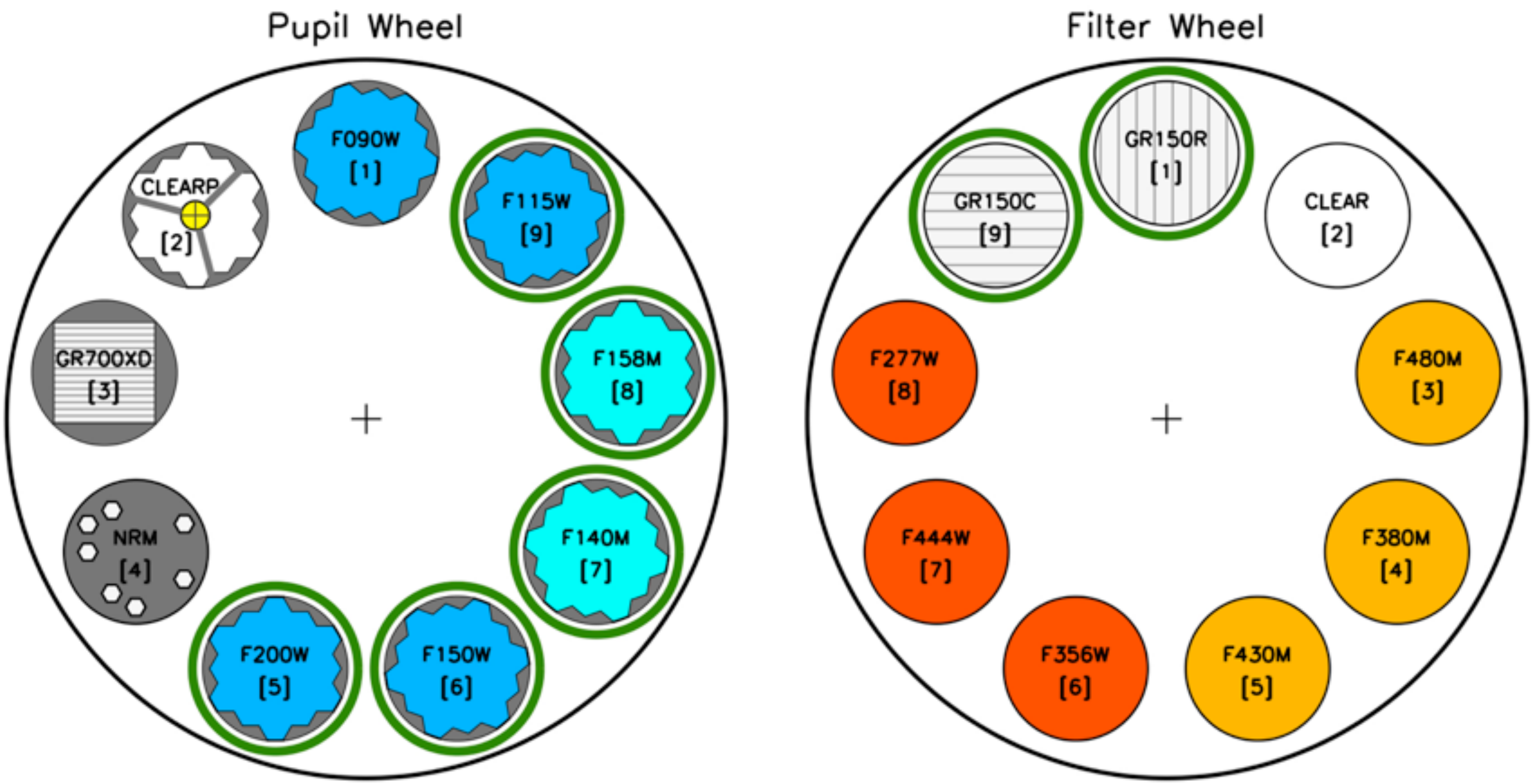
JWST NIRISS

- NIRISS = Near-IR Imager and Slitless Spectrograph
- primary observing modes:
    - single-object R~700 spectroscopy (0.6-3um)
    - non-redundant mask (NRM) interferometry (3.8-4.8um)
    - wide-field R~150 grism spectroscopy (1-2.2um)

- built in Canada
- delivered to NASA in summer 2013
- now at GSFC undergoing integration and testing

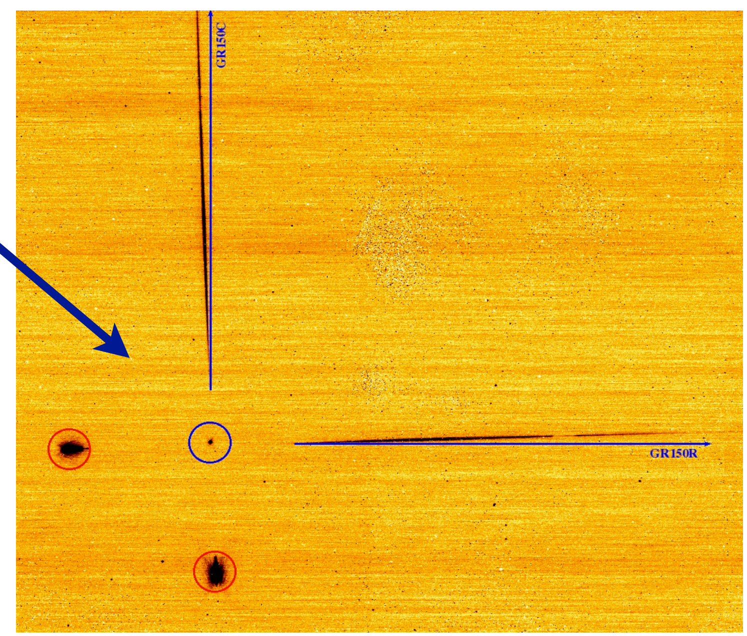
NIRISS wide-field slitless spectroscopy

- NIRISS can do **wide-field slitless spectroscopy** in FOV 2.2' x 2.2'
- Two orthogonal R=150 **grisms** and six blocking **filters** from 0.9 to 2.2 microns



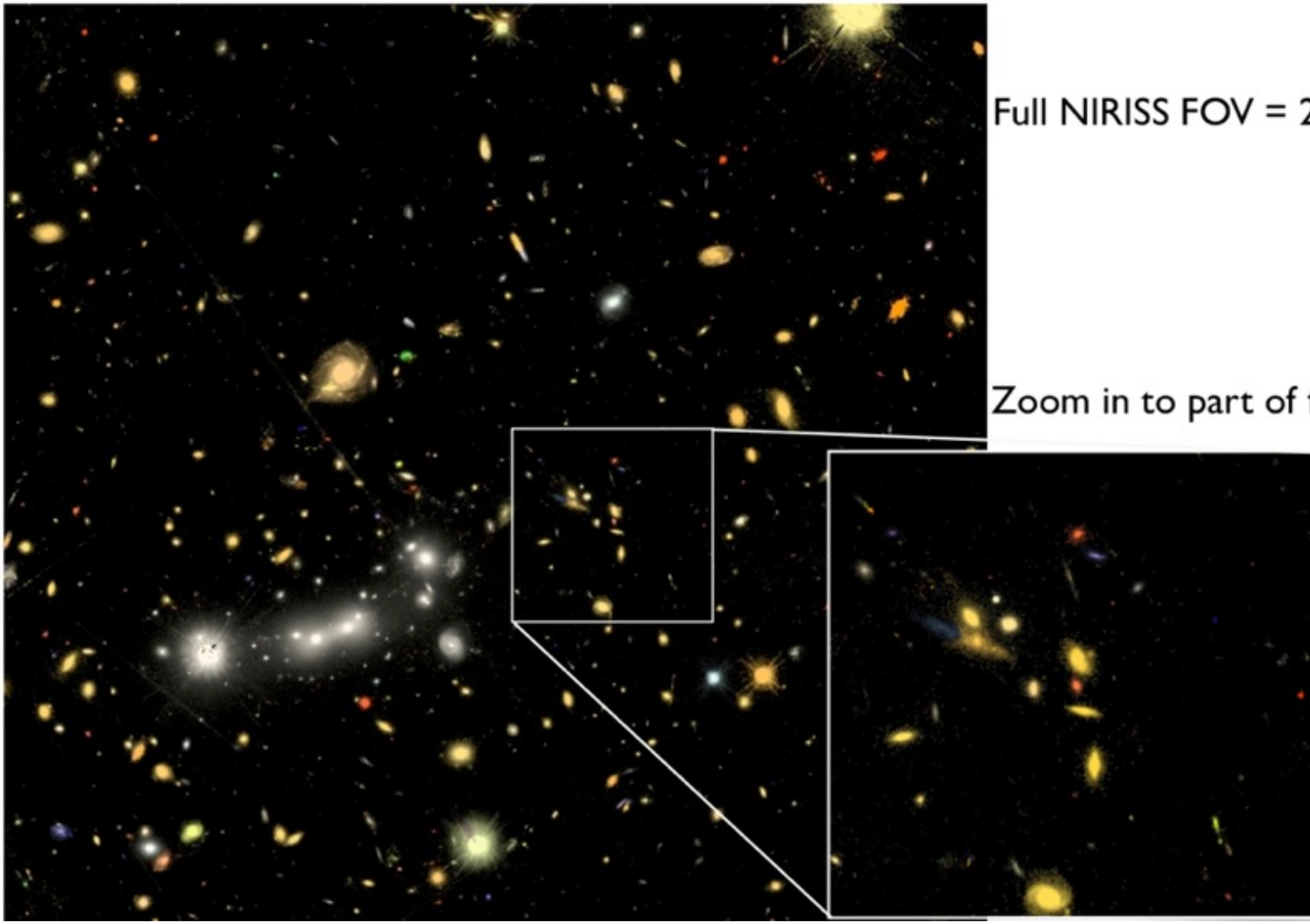
NIRISS wide-field slitless spectroscopy

- Spectra of **all** objects in the field. In a "blank" field there are **~3000** galaxies at mag < 28.
- Almost complete **wavelength coverage** from 0.9 to 2.2 microns.
- At least one strong **emission line** from z=0.5 to z=4.9. Lyα (if present) at 6<z<17.
- Resolving power of 100 to 200. Most lines spectrally unresolved, so a **map of line emission**.
- **Spatial resolution** of 0.06" ~ 0.5 kpc.
- **Cross-dispersed** grisms to mitigate contamination.
- **Point-and-shoot** observing - no target acquisition.
- Ideal for pure **parallels** due to simple operation.



NIRISS wide-field slitless spectroscopy

Simulated NIRISS imaging observation of MACS0647 cluster



Full NIRISS FOV = 2.2’ x 2.2’

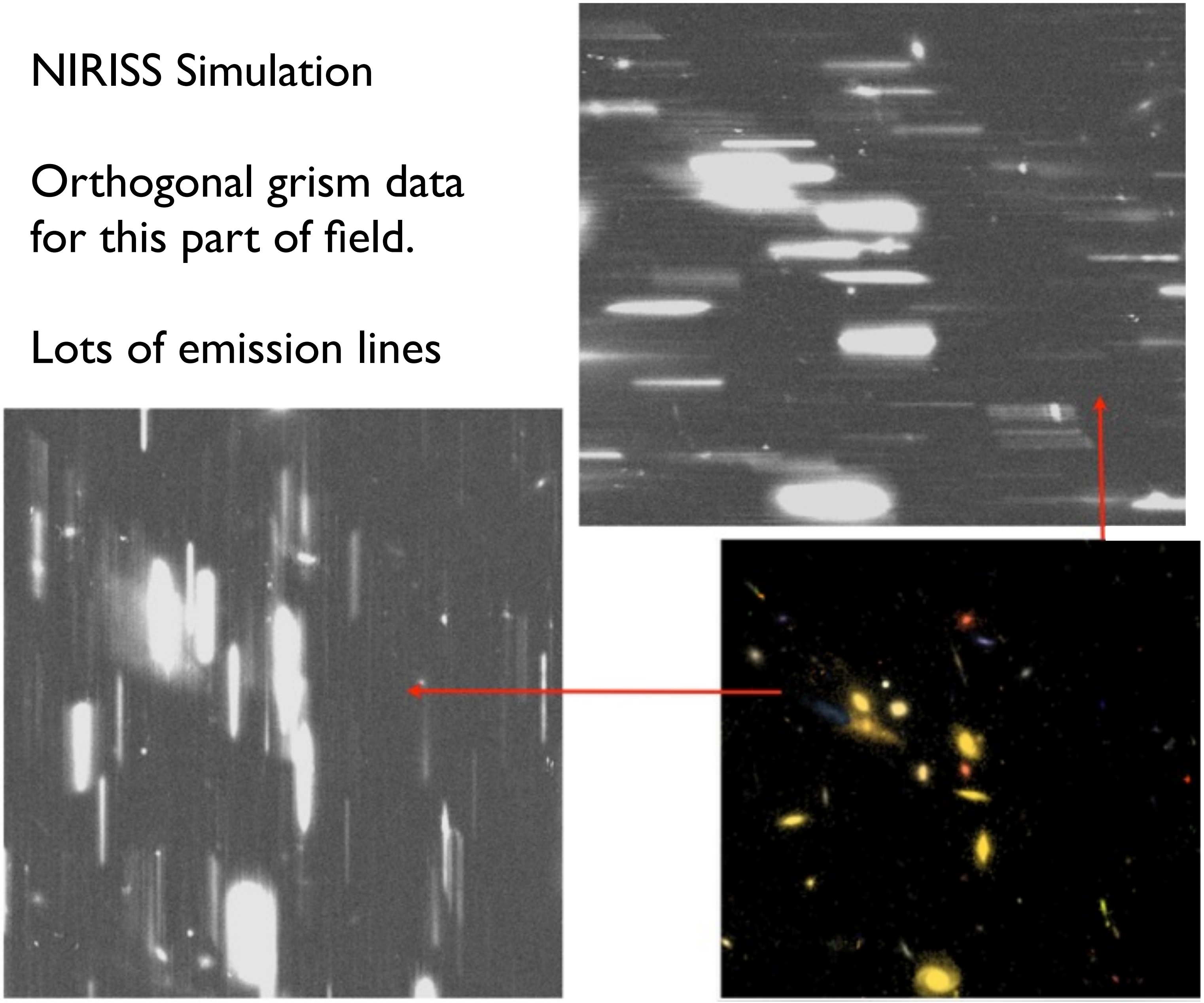
Zoom in to part of field

NIRISS wide-field slitless spectroscopy

NIRISS Simulation

Orthogonal grism data
for this part of field.

Lots of emission lines



NIRISS wide-field slitless spectroscopy

"First Light" science aims:

- Confirm redshifts for LBG candidates
- Discover high-EW Lyman-α galaxies not selected as LBGs
- Measure galaxy spectral slopes, β, for stellar pops, dust.
- Lyman-α EW as a function of redshift and luminosity - reionization
- Spatial distribution of Lyman-α emission, especially when lensed
- Signatures of AGN (e.g. HeII, CIV, CIII]) or Pop III (HeII)
- Physical associations, e.g. groups, clusters

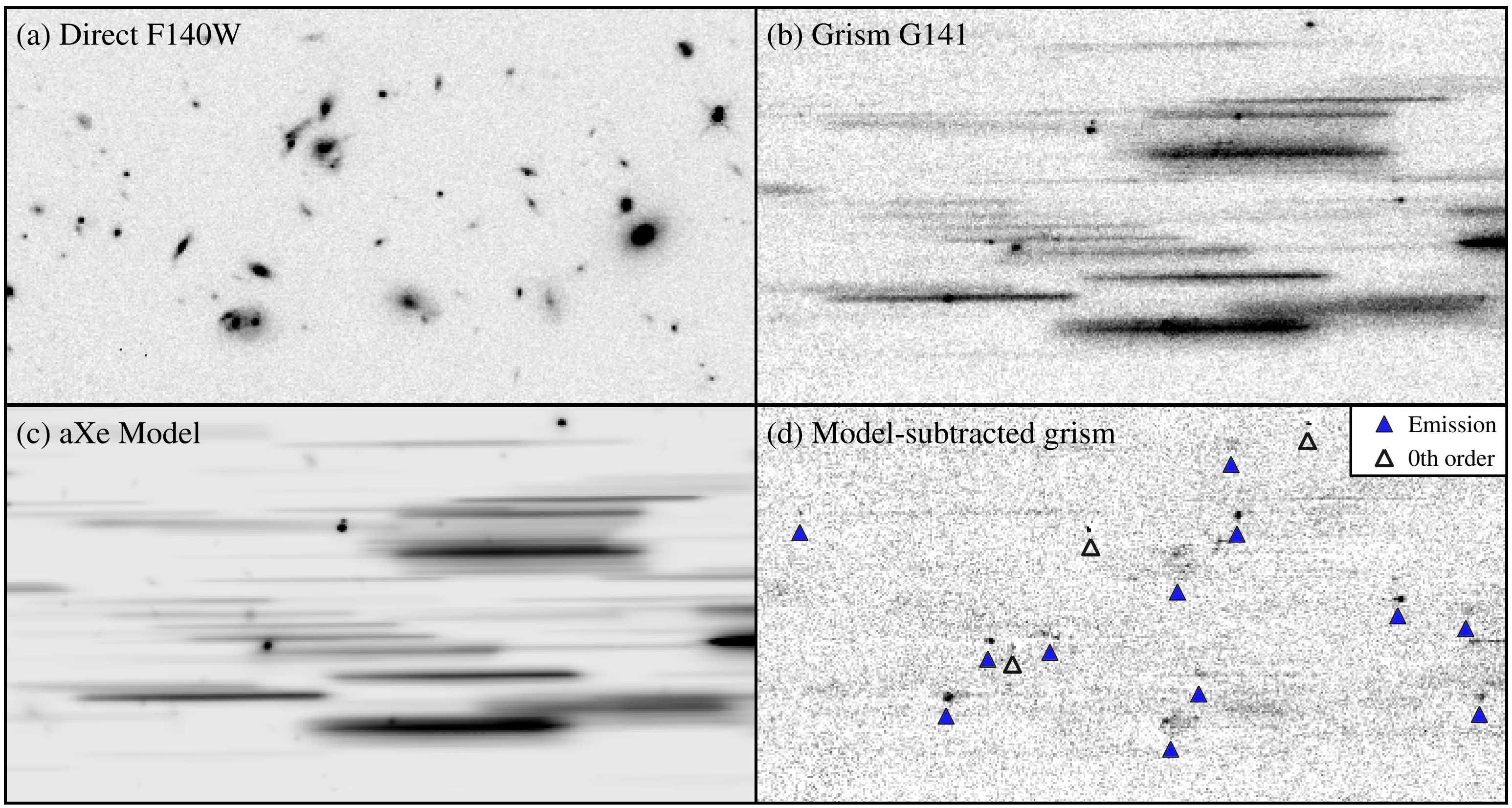
NIRISS wide-field slitless spectroscopy

"Galaxy Assembly", z<5, slitless grism science is exciting:
A low-resolution spectrum for every object in the field!

- Much better than photo-z's:
  redshift catalogs good enough to, e.g., assign galaxies to local environment
- *Total* line fluxes and line ratios:
  SFRs, extinction, metallicity as function of time, galaxy type, stellar mass
- Spatial distributions of line emission:
  where in a galaxy do stars form as function of epoch, galaxy's mass?
  spatial distributions of stellar populations, metallicities

NIRISS wide-field slitless spectroscopy

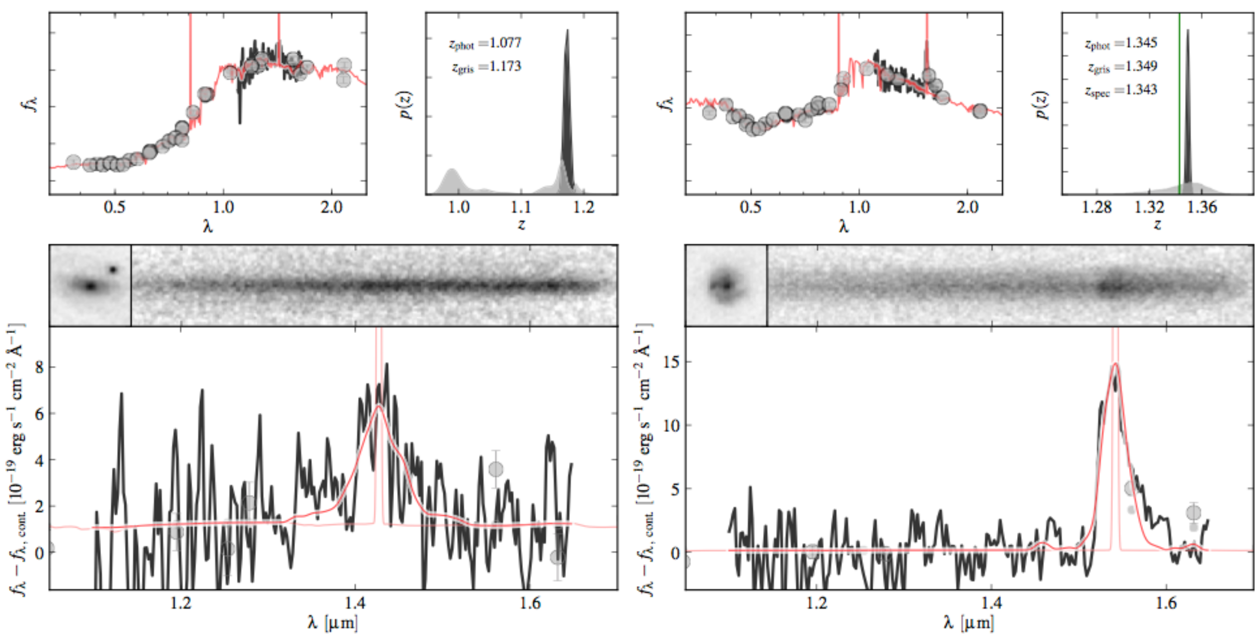
The 3D-HST survey with WFC3-IR has highlighted capabilities of space-based near-IR grisms



Brammer et al. 2012

NIRISS wide-field slitless spectroscopy

<u>3D-HST: good redshifts for every object in the field:</u>

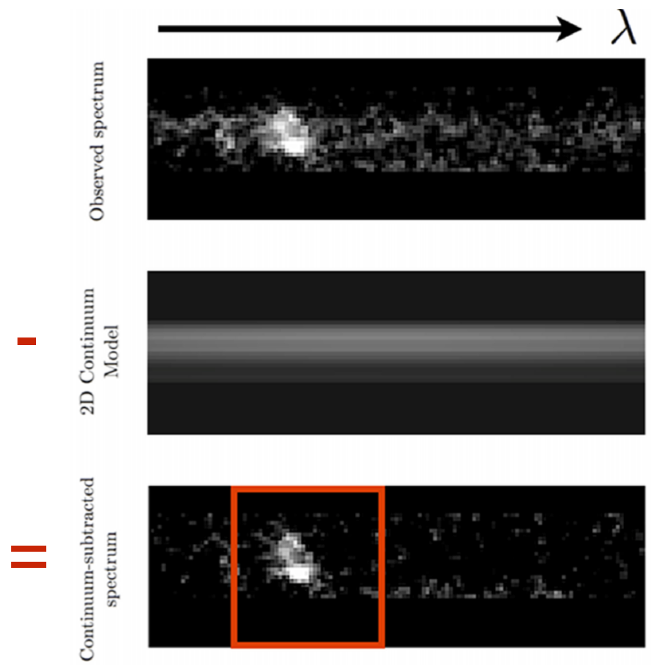


Brammer + 2012

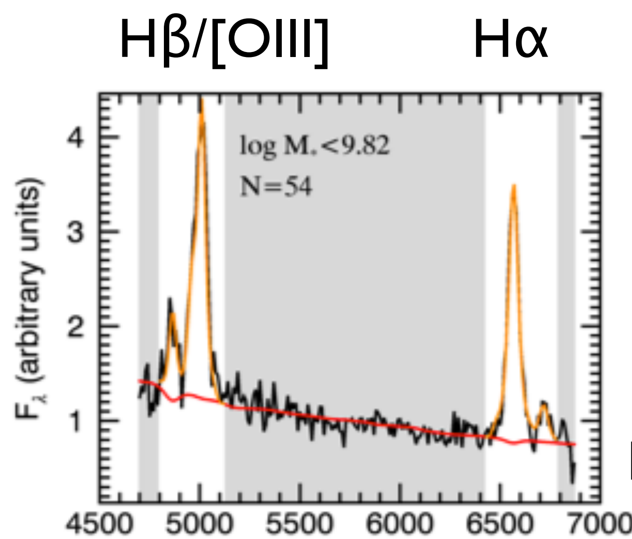
- standard δz_{phot} too big for ID'ing environment (local density), true galaxy pairs
- but with grism δz_{grism}~10x better than δz_{phot}.
- This is particularly powerful when combining z_{grism} & z_{phot}

NIRISS wide-field slitless spectroscopy

3D-HST: line fluxes and line ratios:



Schmidt + 2013

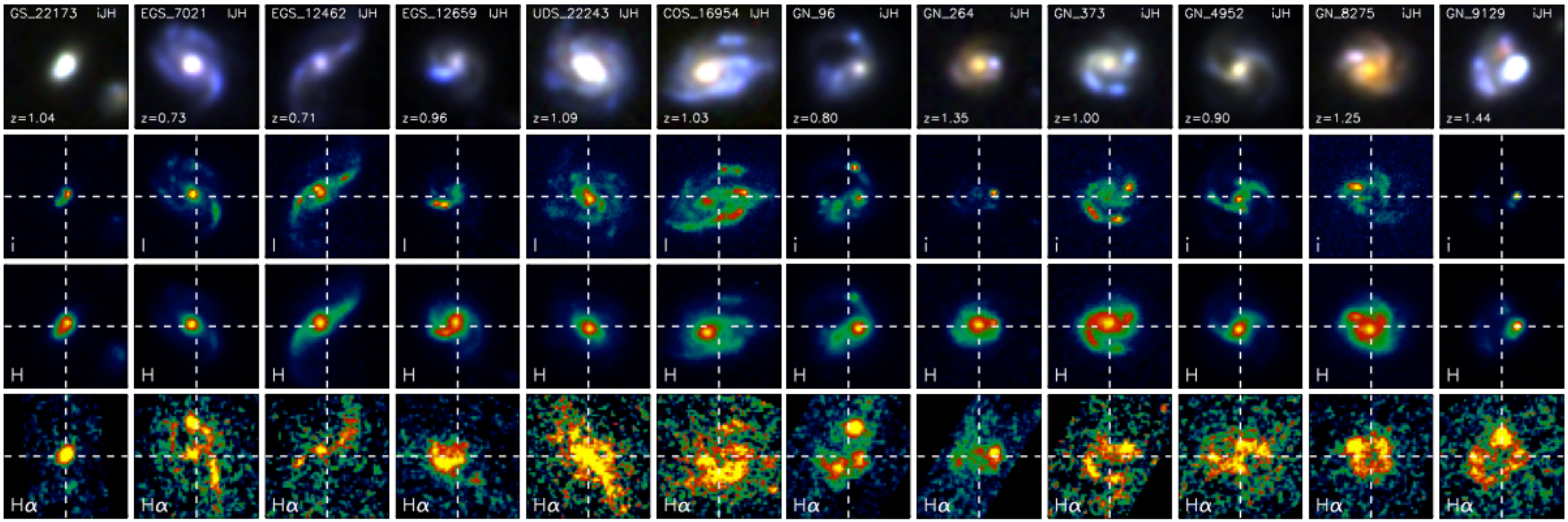


Price + 2012

- Total fluxes. No slit losses, no NB wavelength uncertainty.
- Emission line luminosity:
  - ➡ star formation rate, extinction, metallicity
- Absorption line strength:
  - ➡ age - more difficult, can be done if bright or by stacking

NIRISS wide-field slitless spectroscopy

3D-HST: spatial distribution of line emission



Wuyts + 2014

- Line map → star formation map
- Line ratios → metallicity, reddening, AGN signatures, stellar population gradients

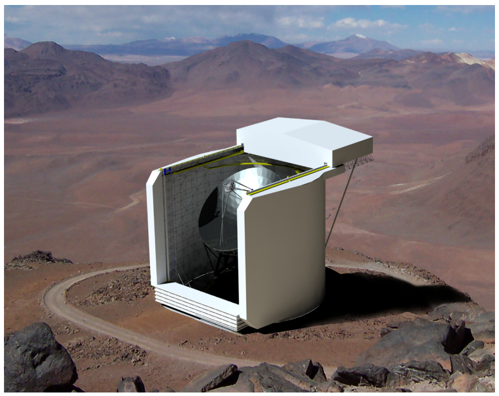
JWST

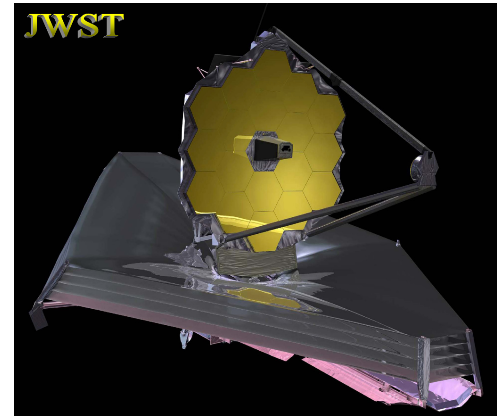
- We are very excited about JWST in Canada
- great for First Light science
- fantastic for "Epoch of Galaxy Assembly" at z=1-5
- NIRISS science team plans to spend ~1/2 its GTO time (200hrs) in the wide-field slitless spectroscopy mode

- But: JWST has a small FoV:
  NIRCam = 10□'; NIRISS = 5□'
- JWST will have a hard time finding rare, luminous objects that (a) probe extreme of physical parameter space and (b) can be followed-up in detail even with ELTs

WISH in the Canadian context

CCAT





JWST

ALMA

TMT

Gemini (x2)

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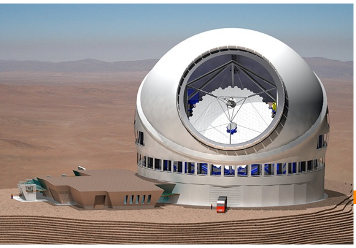
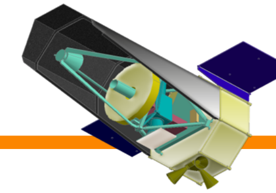
Synergy with TMT

- Canada one of the first partners
- Canada responsible for:
  - enclosure
  - NFIRAOS AO system
- $300M (planned Canadian share)



Synergy with TMT



Most JWST very-high-z objects will be too faint for spectroscopy with ELTs

…but…

TMT will be able to study the rare, luminous objects that WISH finds.

WISH Ultra Deep Survey:

(100deg^2, 28AB, 1-4um 15h integration)

e.g.: z = 11-12 galaxies ~26.5AB ~5/deg^2 ~27AB ~20/deg^2

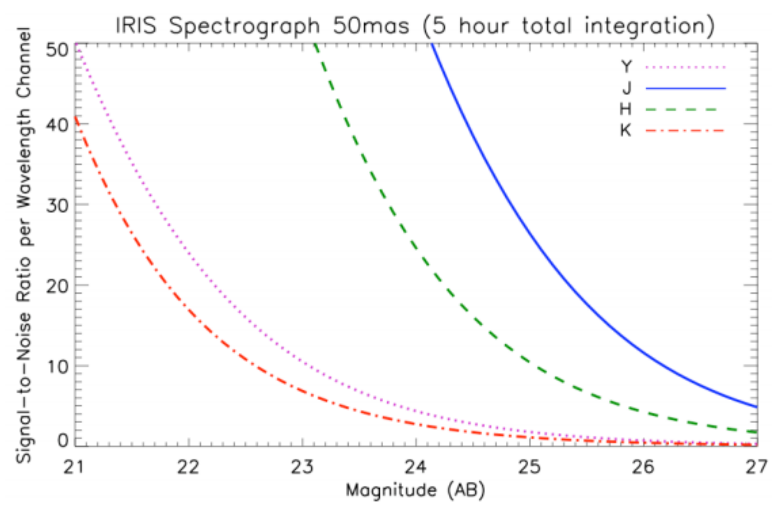
TMT/IRIS:

0.1” aperture AO-assisted

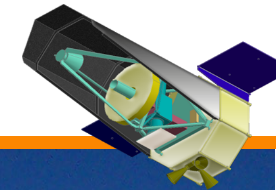
Continuum H-band, 5hrs, S/N= 2-3

26-27 AB (R~4000 resolution unit)

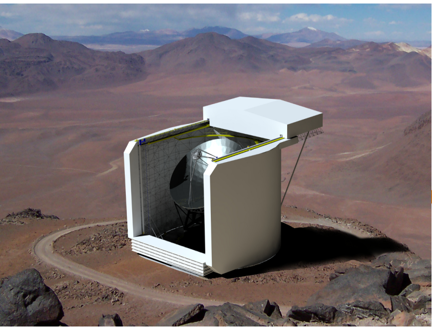
Wright et al. 2010
0.1” aperture / point source
0.05”/pix



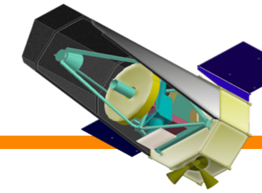
Synergy with CCAT

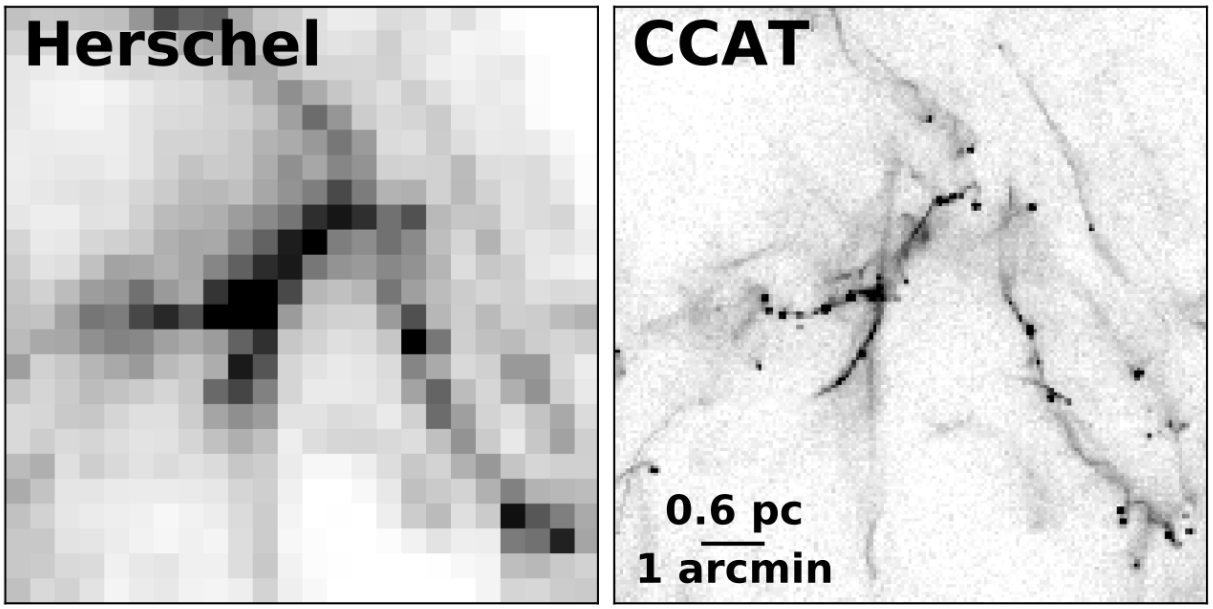


- proposed 25m sub-mm telescope in the high Atacama
- 1000x faster mapping speed than SCUBA2
- consortium of US, German, and (10) Canadian institutions
- first light ~2020



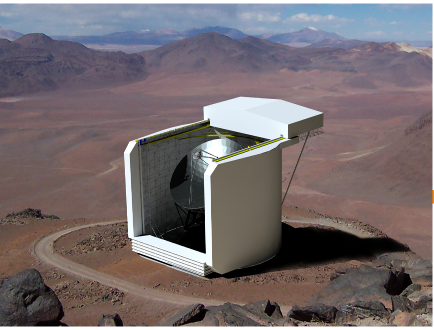
Synergy with CCAT



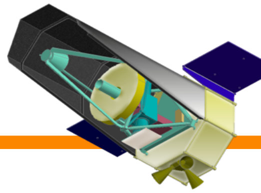


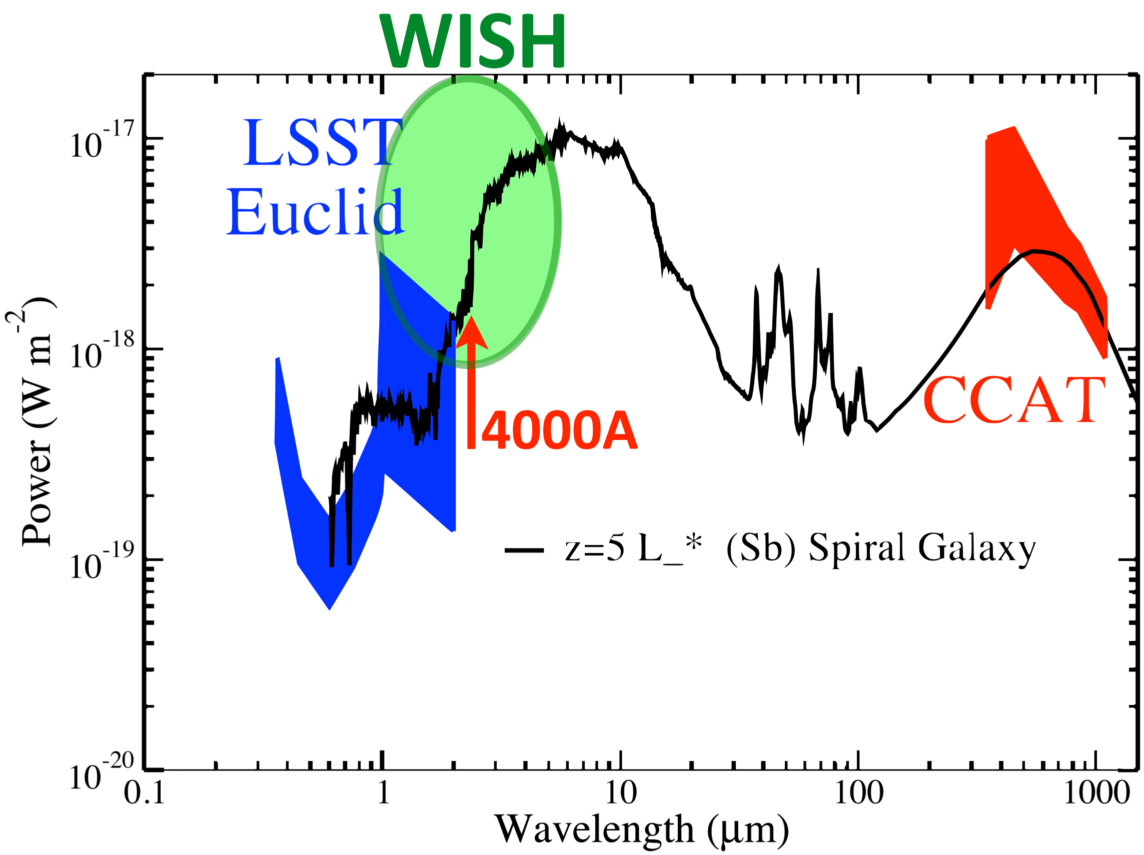
Hershel vs CCAT at 350um: a simulated image of a molecular cloud

- CCAT designed for large surveys and large statistical samples
- CCAT will survey >100 deg^2 at 350, 450, 850um: i.e., the very dusty universe
- WISH will sample around 4000A at z~5, => measure stellar masses etc. of CCAT objects



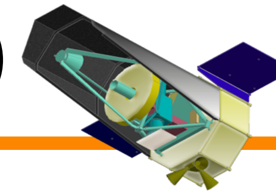
Synergy with CCAT





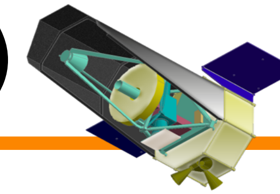
- Strong case for pushing the studies of sub-mm galaxies in early cosmic epochs, z~5
- WISH will sample around 4000A at z~5, => measure stellar masses etc.
- WISH an excellent follow-up instrument for characterizing high-z very dusty galaxy

WISH and the assembly of galaxies (z=1-5)



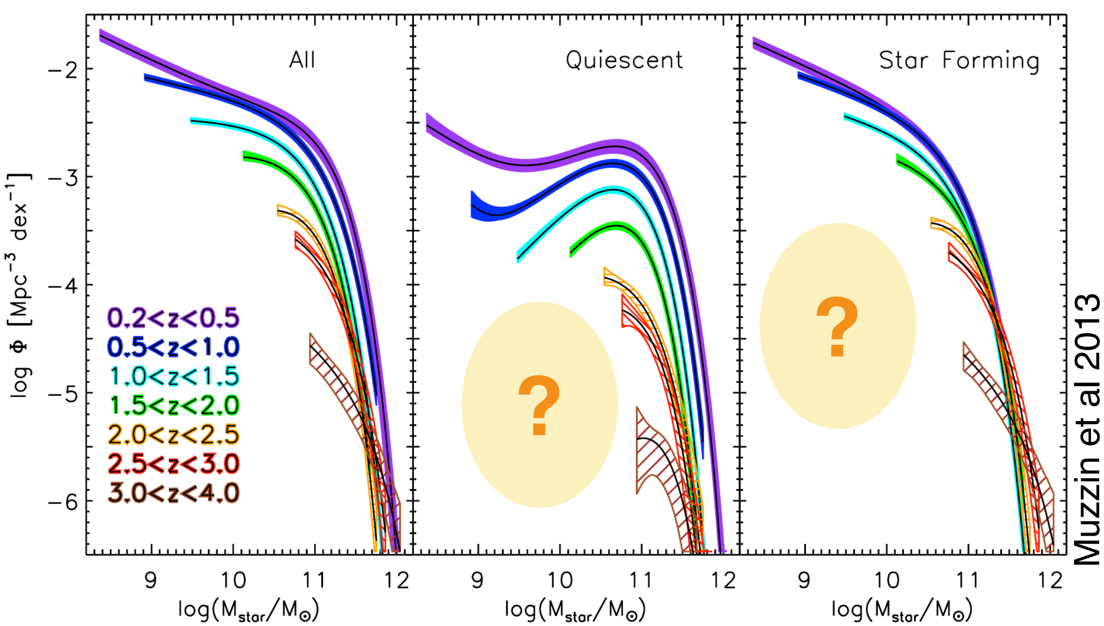
- WISH will be great for "first light" science
- it will be even better for the "epoch of galaxy assembly" at z~1-5

WISH and the assembly of galaxies (z=1-5)



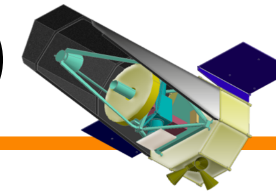
- z = 5 ⇢ 1 is where much of galaxy-building takes place
- We still have much to learn at these epochs:
  - how much stellar mass has been assembled?
  - how important is environment?
  - how do galaxies go from star-forming to quenched?
  - what role do interactions and AGN play?

One example of our ignorance:



- Current surveys barely resolve the peak in galaxy formation efficiency at 1<z<3
- Evolution of galaxies with $M<10^{10}$ is largely unconstrained.
- WISH will reach $10^9 M_\odot$ for quiescent galaxies and $10^8 M_\odot$ for star-forming galaxies at z~3

WISH and the assembly of galaxies (z=1-5)



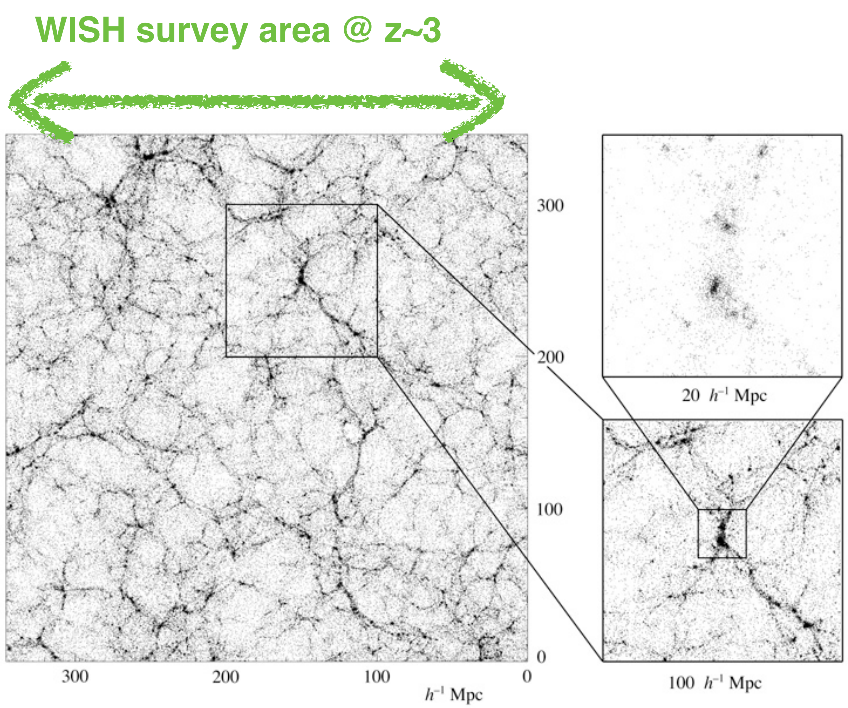


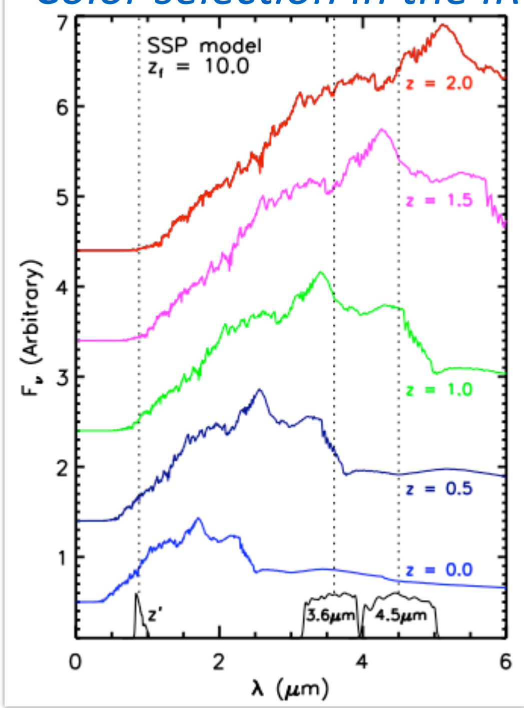
Fig 8.16 (D. Weinberg) 'Galaxies in the Universe' Sparke/Gallagher CUP 2007

- Galaxy evolution at z~0 seems to depend on local environment (e.g., Peng et al. 2010)
- This may also be the case at high redshift!
- —> we need large galaxy samples across a range of environments
- —> WISH

Clusters at z=1-2

- Galaxy evolution in dense environments
- Growth of structures —> measurement of cosmological parameters
    - independent of geometric methods (SN, CMB, BAO)
    - on of very few ways to test GR on very large scales
- These goals require large samples (=large areas) at high redshifts

Color selection in the IR:



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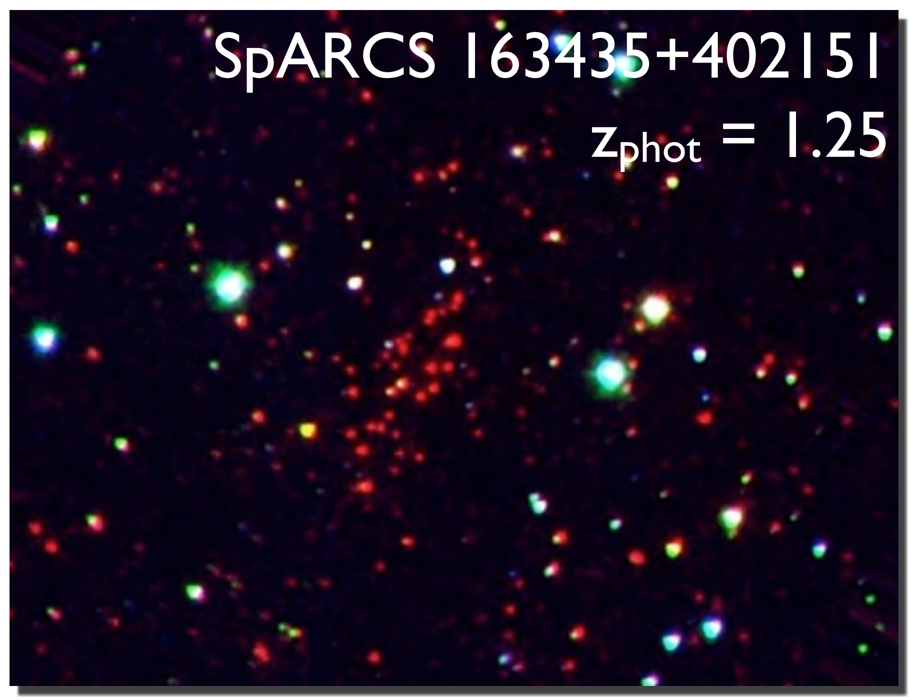
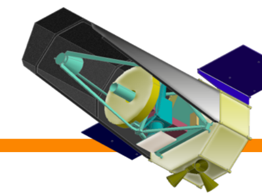
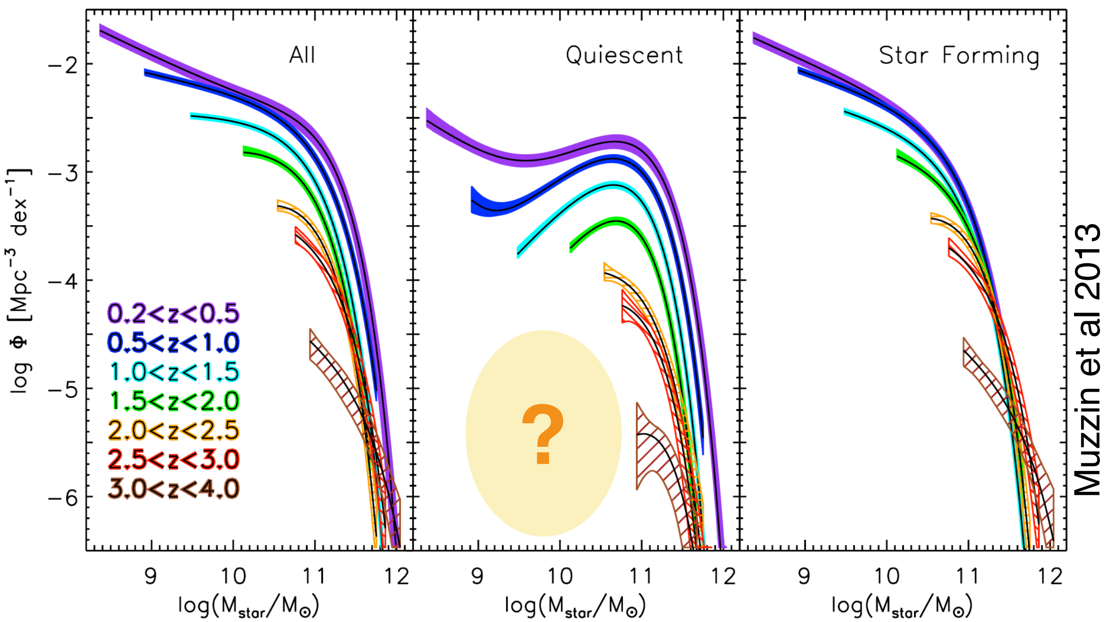


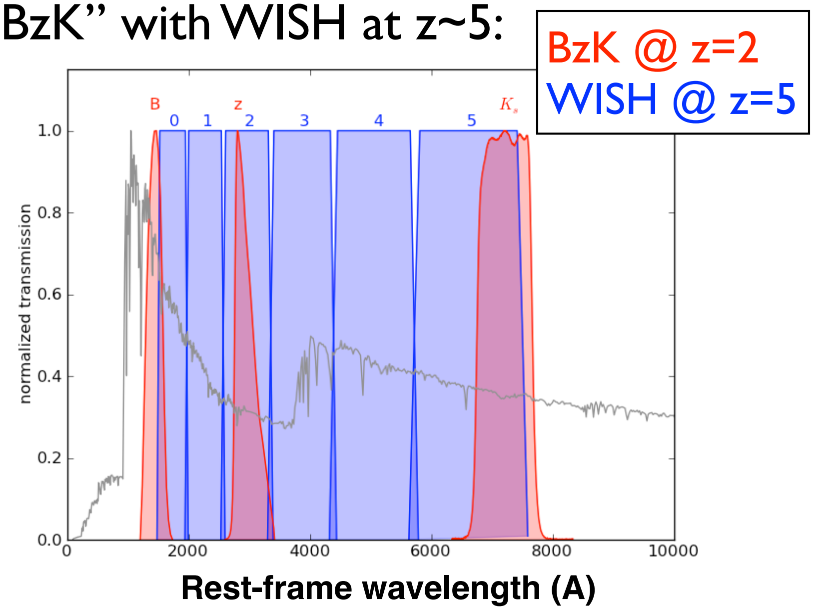
Muzzin et al 2013

Fossil record of first light galaxies





"BzK" with WISH at z~5:



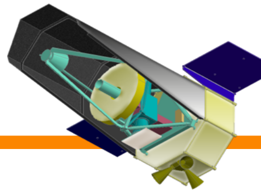
Quiescent galaxies at z~5:

- fossils of z≥10 star-forming galaxies
  - this is another way to study the First Light objects!!

- detectable to M~10^{10} $M_{\odot}$ with WISH W5 filter (26AB)
- even their numbers are unconstrained: ~1–100/sq deg/Δmag ??

  ⇛ need ~100 sq deg ⇛ WISH

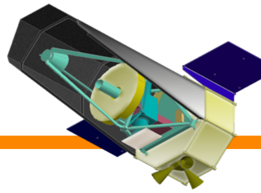
z<5 summary



- Characterizing the growth of galaxies
- Study dependence on environment, which seems to be key
- Large samples of z>1 clusters: for galaxy evolution and for cosmology
- Characterization of ultra-dusty CCAT galaxies out to z~5
- z~5 red-and-dead galaxies: another way to study First Light objects

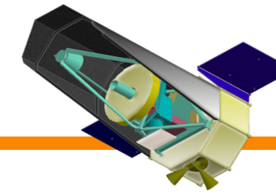
z=1-5 is as exciting as First Light!

Canadian perspective in conclusion



- Strong scientific interest in Canada, spanning a wide range of science
- I would say z~1-5 as exciting (or even more exciting) than First Light science, given the vast range of possible programs at z<5
- WISH is very complementary to other Canadian projects (JWST, TMT, CCAT)

Canadian perspective in conclusion



- We have identified the WISH filter exchange unit (FEU) as matching Canadian capabilities and interests. This is the potential Canadian contribution to the project.
- Canadian Space Agency (CSA) does not have a system of regular proposals: no clear mechanism to propose for funding
- We hope upcoming proposal submissions in Japan and US will spur the CSA to action